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COAL, SMOKE, AND SEWAGE,

SCIENTIFICALLY AND PRACTICALLY CONSIDERED;

WITH

SUGGESTIONS FOR THE SANITARY IMPROVEMENT OF THE DRAINAGE OF TOWNS,

AND THE

BENEFICIAL APPLICATION OF THE SEWAGE.

BEING THE SUBSTANCE OF A PAPER READ BEFORE THE LITERARY AND PHILOSOPHICAL SOCIETY OF MANCHESTER.

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COAL, SMOKE, AND SEWAGE,

SCIENTIFICALLY AND PRACTICALLY CONSIDERED.

There is no subject of a purely material character of more pressing importance to the public well-being than the Sanitary condition of our large towns. The inevitable tendency of our Manufacturing and Commercial activities to concentrate our population in large masses, while it presents many features of advantage to health and longevity, has other results of quite a contrary tendency; among the chief of these are, the accumulation of solid, liquid, and gaseous excreta, resulting either directly or indirectly from human and animal life, and also the gaseous emanations from the various manufacturing and culinary processes so largely carried on where human beings are so densely massed together, as in our great centres of industry.

This subject has repeatedly been pressed upon public attention during the last quarter of a century, in a shape that could not be mistaken. An epidemic of a dreadful and deadly character, and which has, in all its visits, chosen its victims from among those who were most deeply immersed in liquid and gaseous filth, has roused the public mind, during its continuance, to convulsive efforts in the direction of purification. These efforts, though made sincerely and heartily, were, however, generally guided by only a small amount of knowledge and judgment; and as soon as the impelling cause was removed matters resumed their ordinary condition, and until Cholera again appeared, cleanliness was at a discount.

But as it became more and more evident to thoughtful and benevolent men, that unless a radical change in our social condition were effected, Cholera would become periodical in its attacks, and other epidemics would also increase in prevalence and fatality, Sanitary movements began to take hold of the public mind. Some engaged in these movements from motives of self-preservation, and many others from motives of a benevolent character. Associations for the purpose of sanitary improvements were subsequently formed, and now exist in many of our towns. By these the subject has been kept from sinking into oblivion; and while 'the more active members have been busying themselves in the discovery of local and particular cases, and urging the authorities to pounce upon an open sewer or cesspool, or an unfortunate chimney whose emanations of black smoke were more than usually dense and noticeable, and by these exertions have been conferring their quota of benefit on the community;—the more intelligent and philosophical have been looking out for some comprehensive and practical scheme, by which the confessed difficulties of the subject can be overcome, and by which our towns can be economically and certainly made agreeable and wholesome places for human habitation.

In a matter so comparatively new as the Sanitary movement undoubtedly is, it was to be expected that great mistakes would be committed, and that considerable zeal and energy would be expended to obtain results which better knowledge would subsequently shew to be worthless.

There are two forms in which the evil to be remedied presents itself, namely, the visible and the invisible. The visible contaminations are those forms of filth of which our drains and sewers and cess-pools are made the receptacles, and the results of our coal combustion, both in our domestic and manufacturing operations,—which dim the atmosphere, making all around at times disagreeable to the eye and some of the other senses, and covering almost every object with a sooty deposit. But these, although the most apparent forms of our un-Sanitary condition, are certainly not the most fatal. The invisible effluvia which are continually emanating from decaying and excrementitious matter, and the invisible gases from our coal combustion, are the more deadly evils, and also the more difficult to be met by a practicable *remedy*. We may remove the solid and liquid contents of our cess-pools and sewers; and even in London, where the excreta of two millions and a half of people are converting the Thames into a foul-water drain, these may be intercepted before they reach the river, and conveyed away (at an expense of from five to ten millions) far from the city, and be poured into the tidal stream at a point where they will be sufficiently diluted. But what then? Unless this clumsy scheme be accompanied by what has not yet been mooted as a part of it—some mode of freeing the inhabitants of London from the impurities of the liquid abominations below, which this scheme will as its first effect only more fully concentrate—how is the health of London to be improved thereby? No amount of trapping will confine these gaseous effluvia, every breath of which is surcharged with fever, and every leak from these drains will prove a nucleus for cholera in its most devastating form.

Here, however, the visible evil is at least attracting attention, and is hastening on a remedy, such as it is, while the invisible but more fatal form of the evil is almost ignored, or at least has little attention bestowed upon it.

Again, in our atmospheric condition, the visible evil is the apparent and palpable carbon,—the black smoke of our fires and furnaces. This has in our manufacturing towns especially, and also in the metropolis, become so crying an evil, that even a legal remedy has been resorted to, and the law demands, and in some instances obtains, an abatement of the noxious practice. But the invisible evil is completely ignored, the Smoke Nuisance is held as *the* evil of our atmospheric condition. "Burn your smoke!" is the united cry of the Sanitary Association, the public, and the law. The visible evil here has attracted all the attention of the learned and the unlearned; and hardly a solitary voice has yet been heard *against* the smoke-consumption crusade, or the sanitary smoke-consuming mania, if I may be allowed the expression;—for in this case not only does the cure of the visible not effect the cure of the invisible evil, but every effort to effect the cure of the one only increases the noxiousness of the other. Perfect freedom from smoke would, if accomplished, only increase the evil arising from the purely gaseous results of combustion.

This, then, being one of our sanitary evils which appears to me to have been almost entirely ignored, I shall endeavour to shew what it really is, and what it may become; and in connection therewith I shall consider the *economics* of our Coal Consumption, present and prospective, and shall then point out what I venture to suggest as a practical remedy for the evil in all its forms.

From these remarks it will be apparent that I do not sympathise with the views of those whom I shall designate as the Sanitary Smoke Consumers: in their motives I most heartily concur. I hold that our scientific discoveries and inventions in the Arts should not stop short with the acquisition of money; but as wealth is chiefly valuable as a means of insuring and increasing human happiness, and as sound health is a primary requisite to the happiness of the individual or the community, a more wise or beneficent effort cannot be made to increase the material comfort of our populations than by giving them a pure air, and thus surrounding the human body with that first requirement for vigorous health.

In all our benevolent enterprises, it is not only necessary that the motive be good and the end sought after really beneficial, but it is quite as needful that the means employed be wisely adapted to gain the object sought. And at this point I part company with the sanitary smoke consumer, and while demonstrating that to the mere economist there is great inducement to get rid of all visible smoke, as a consequence of his obtaining perfect combustion of fuel, I would at the same time say to the sanitary smoke consumer that he had better not interfere further, as every step he takes in enforcing the consumption of smoke will only tend to deteriorate the atmosphere, and that every cloud of visible smoke he is successful in dispelling is only making way for a more baneful though invisible agent; that every atom of solid carbon which he prevents from floating innoxiously—I may almost say beneficially—in the atmosphere, *becomes by combustion either an atom of poisonous carbonic acid, or more poisonous carbonic oxide*, which gases, if not carried off by the atmospheric currents, or rapidly diluted by diffusion, would settle down among our dwellings, and render our atmosphere poisonous and our towns almost uninhabitable.

Not only does every effort at more perfect combustion eliminate a proportionately larger amount of these two gases, but there is another substance which, as soon as we arrive at perfect combustion, will come into play (but from which we are yet comparatively free, simply in consequence of the imperfection of that process), which the sanitary smoke consumer will find is a demon more potent for evil than he has now any idea of, and to bring which under subjection will require the adoption of means of which at present he has no conception.

Although on this part of the subject, the effects of the coal combustion of our towns on tho *sanitary* condition of their atmosphere is the question of most pressing importance, yet as the economical question is in itself a matter of general interest, and has also a very intimate bearing upon the other, I shall at once divide the subject of our Coal Consumption into two parts, the economic and the sanitary. Being also aware that my statements on an important part of the subject will run counter to generally-received public opinion, I feel it the more necessary, both for the vindication of my own correctness in making these statements, and also for the better chance of convincing those to whom they are addressed, to look at the question from a point where data of a perfectly definite character can be obtained. I shall therefore confine myself entirely to the coal consumption of Manchester. One reason for this choice is, that on this question Manchester is the type of nearly all our manufacturing towns. To Birmingham, Bradford, Leeds, Liverpool, Glasgow, and other places may be applied, to a considerable extent, what is said of Manchester.

But my chief reasons for this restriction are, that we have perfectly reliable data as to the quantity and quality of coal used in Manchester at the present time. The quantity is obtained from a valuable paper on the Statistics of Coal Mining in Lancashire, by Joseph Dickinson, Esq., one of her Majesty's Inspectors of Coal Mines, and read before the Literary and Philosophical Society of Manchester in 1854; and the quality is obtained from various tables which give the constitution of the coal of the Lancashire coal measures, which are exclusively used in Manchester. On one important point, namely, the average amount of sulphur in the coal used, in addition to the tables, I have been able to consult some living authorities, among whom may be named the author of the paper referred to, and Edward William Binney, Esq., who has made the Lancashire coal field his peculiar study, and is, I believe, acquainted with the character and position of every vein of coal that is worked in it; and I have also had the means of obtaining tolerably accurate information as to the actual economical condition of the coal combustion of Manchester down to a very recent period.

In entering, then, upon the economical part of the question, it may be stated, on the authority of Mr. Dickenson, that 2,000,000 tons of coal are annually consumed in Manchester and Salford, which in a question of this kind may be taken as one town. For the average composition of the Lancashire coal I now refer to Table No. 1. This is not presented as perfectly accurate for any one variety of coal, for the difference in composition is considerable, and no two veins are exactly the same; but the list is sufficiently accurate for our purpose, and will not lead us materially astray on any one point. Suppose, then, that we take 100 lbs. of a mixture of the various coals used in Manchester, it will contain as follows:—

4·5 lbs.	Hydrogen	0·5 lbs.	Nitrogen
6·0 "	Oxygen	58·0 "	Carbon (fixed)
24·0 "	Carbon (volatile)	5·0 "	Ashes (silica, alumina, and oxide of iron)
2·0 "	Sulphur		

Coal is sometimes divided into bituminous and non-bituminous. This description is now considered incorrect, as no coal contains bitumen. It has therefore been proposed to call it bituminiferous; and I may say that all the coal of the Lancashire coal measures is of that kind. With non-bituminiferous coal no black smoke is produced, as there is no volatile matter in it, or nearly none, and its constituents can only be volatilised by combustion.

To have a clear idea of the Economic as well as of the Sanitary part of the subject, it will be necessary here to go rather minutely into the process of combustion, and to shew in detail what this process is to which we have now to subject the coal whose constituents we have thus described.

Since the time when the Phlogiston theory of Stahl was exploded, which defined combustion to be the evolution of phlogiston, a substance or principle which existed in all combustible bodies, and by the possession of which they became combustible (and which substance or principle was evolved when the bodies were burned, and as light, heat, or flame was produced, as the case might be);—since this theory was found to be untenable, and the phenomena became better understood, combustion has generally been held to be merely the union of oxygen with the combustible body, that union taking place in definite proportions or atomic weights, according to the beautiful atomic theory of Dalton, and the substance resulting from the combustion of any body being merely a oompound of that body and oxygen in one or other of these definite proportions.

Although this is found not to be strictly correct, as there are cases where all the ordinary phenomena of combustion occur without oxygen being present, yet for our present purpose it will be quite sufficient, and strictly true, to take the combustion of coal to be simply the union of oxygen with the combustible constituents of the coal; that process, if perfectly conducted, leading to the union in all cases of the same quantity of oxygen with a given weight of each of these constituents, and invariably producing in these circumstances the same amount of the definite resulting compound. Thus, to refer to the table No. 2:—

4·4	Hydr.	unites with	35·2 Ox.,	forming	39·6	Water.
24·	Vol. Carb.	“	64·	“	88·	Carbonic Acid Gas.
2·	Sulphur	“	2·	“	4·	Sulphurous Acid Gas.
58·	Fixed Carbon	“	154·6	“	212·6	Carbonic Acid Gas.

These results will be invariable, provided the process of combustion be so conducted as to afford the conditions for insuring its being complete. These conditions are, a sufficiency of oxygen brought into proper contact with the combustible body at a sufficiently high temperature. If the process be incomplete, one or other of these conditions must be wanting.

Now, as there is no doubt that both of them are possible, and will ultimately be made practicable, it is of great importance that we have a definite idea of what is obtainable by perfect combustion in an economical point of view; and, comparing this possibility with our present average attainments, we may then be able to estimate the probable gain that is before us, as the difference between imperfect practice and sound theory is always the measure of possible improvement.

Now we are not only in a position to say positively that the combustion of coal, perfectly conducted, will produce always the same results, but from many carefully conducted experiments we are also able to tell the exact amount of heat that will be given out during the process, each of the constituents of coal having been separately and repeatedly subjected to combustion, and the results, carefully noted by various experimentors, have furnished complete data on which the utmost reliance may be placed. Heat is, however, rather a subtle body, and chemists have not yet been able to weigh it or take its dimensions in any tangible shape. It must therefore be measured by some of its most apparent effects; and, fortunately, the one generally chosen in these experiments is one that is peculiarly applicable to the investigation of combustion as a question of economy.

It has been ascertained that when a given quantity of hydrogen gas is subjected to combustion, and all the heat or caloric evolved in the process is accurately applied to the heating and evaporation of water, it will increase the temperature from 60 degrees of Fahrenheit, and convert into vapour of 212 degrees, a certain quantity of that fluid. Thus an accurate measure, universally applicable, is obtained. We are also in possession of equally reliable data in regard to the other combustible constituents of coal, from the results obtained by a number of chemists, among whom may be named Dalton, Lavoisier, Despritz, and Dulong; and on the average results obtained by these and other experimentors, the table to which I shall now refer is based. Taking the combustible constituents of the coal, we find that—

1 lb. Hydrogen in burning produces heat = 50· lbs. Water evaporated.
1 lb. Carbon into Carbonic Oxide " = 4· " " "
1 lb. " " Carbonic Acid " = 11·66 " "
1 lb. Sulphur " Sulphurous Acid Gas " = 4· " "

Upon this we can construct the next table, giving us the full amount of water heated up from 60 degrees and evaporated by 100lbs. of coal, constituted according to the table, and all its elements subjected to perfect combustion:—

4·4 Hydrogen .... at 50· = 220· lbs. Water evaporated.
24· Volatile Carbon .... " 11·66 = 279·84 " "
58· Fixed " .... " 11·66 = 676·28 " "
2· Sulphur .... " 4· = 8· " "
1184·12

These are the purely theoretical results; but in order to give a just estimate of what is possible in practice, we must take into account that the water is not generally thrown into our steam boilers at 60 Fahr., but, by the arrangements made for using the heat of condensing steam, is more generally at 160 Fahr. We must therefore, in justice to the theoretical calculation, add this to the amount that ought to be evaporated. But 100 degrees Fahr. upon 1184lbs. is a little more than equal to the evaporation of 100 lbs. of water. This, then, brings the quantity theoretically evaporable to 1285 lbs. of water, by perfect combustion of 100 lbs. of coal, provided all the heat is so applied. But here a deduction must be made: by the Table No. 2, it will be seen that the combustion of these constituents of the coal will require 255·8 lbs. of oxygen. To afford this weight of oxygen, it will be necessary to pass through the furnace 1148· lbs. of atmospheric air. Now, taking the air at 60 degrees when it enters the fire, and the resulting gases after combustion being nearly the same in volume, at 260 Fahr., we have thus to calculate a loss of 200 degrees of sensible heat on all this weight of gases passed into the chimney. To arrive at anything like accuracy as to this loss, we must take into account the specific heat of these gases; and as the nitrogen of the air forms the largest portion of the gases, we may be satisfied with the specific heat of that body, which does not materially differ from the others, and is the same as air.

The specific heat of air, as compared with water, is as ·26 to 1. To find, then, what heat is lost by the gases, or what amount of water that heat would evaporate, we must multiply the 1148· lbs. of air by ·26, which will shew that the heat lost by the gases passing into the chimney at 260 Fahr. would heat 298 lbs. of water 200 degrees, or is equal to the evaporation of 60 lbs. of water at 160 Fahr. This 60lbs. of evaporation has then to be deducted from the theoretical quantity of 1285 lbs. before we get to the attainable evaporation. Suppose we also deduct 25lbs. for radiation from furnace doors and into the ash-pit, and for heat communicated through the brick work, we arrive at 1200 lbs. of water at 160 Fahr. as the quantity of water which would be evaporated by perfect combustion of 100lbs. of Lancashire coal.

After making all these deductions, it may still be considered that something is due to the impossibility of arriving at perfect theoretical results in actual practice; but this I leave to the consumers of coal, again reminding them that sound theory has fixed the limit of what can be attained; and until they reach that, their practice is imperfect.

Mr. John Graham, calico printer, favoured the chemical section of the Manchester Literary and Philosophical Society, a few years ago, with the results of a number of large experiments made at the Mayfield Print-works, on coal from different pits, and on boilers of different constructions, and also different modes of firing; the quantity of water evaporated per pound of coal for every experiment being given. I have not the means of consulting that paper at present, but, as far as my recollection serves, the results varied from under 6 lbs. of water to under 8 lbs. of water for 1 lb. of coal. I have also the statement lately made to me of a gentleman whose business engagements should make him pretty accurately acquainted with what is now generally done in Manchester, and he affirms that, although some parties may get 6½ lbs. to 7 lbs. per 1 lb. of coal, yet the average does not exceed 5 lbs. This, if the fact—and I can neither substantiate nor contradict it—is a most astounding one, and requires to be deeply pondered by those connected with Manufacturing operations, as evidently showing that in one part of our economics much has yet to be done. This is evident when we consider that, assuming this statement to be correct, then of every pound of coal used in our manufacturing operations, about 4-10ths are made available and yield useful results, while nearly 6-10ths of it are wasted so far as practical benefits are concerned, and consequently, that of all the immense quantity of coal consumed in manufacturing operations in Manchester, which is estimated at 1,000,000 tons, 416,600 tons are represented by the water evaporated or work done, while 583,400 tons are represented by the waste that is sent in the form of carbon or carbonic oxide through our large chimneys.

I do not feel it my duty here to go into the legion of patented inventions for consuming smoke and economising fuel which are now crowding the patent lists. Many of these no doubt contain valuable suggestions,—and partially effect the object. But no one of them contains all that is necessary, and many of them display great ignorance of the laws of combustion. One of these smoke patentees is so paradoxical as to say that smoke cannot be burned, and that in order to consume it you must do so before it is made. This is simply absurd. All black smoke is composed of or contains particles of combustible matter, and if combustible they can be burned.

This leads me to mention a point of some importance, which seems not to have been sufficiently if at all observed, namely, the radical difference between the smoke of our dwelling-house chimneys, which proceeds from our domestic open fires, and that which comes from our tall chimneys, proceeding from closed furnaces. All persons will have observed that our dwelling-house smoke is seldom dark in colour, being generally of a light grey, approaching to white; whilst the smoke of our manufactories is almost invariably dark in colour, and when dense it is quite opaque. Now this is a difference not only in appearance but in essential character. The smoke from our domestic fires is a very heterogeneous composition, while that from our furnaces is, I believe, much more simple. Our domestic fires, though vomiting forth a sufficiently noxious compound, have not yet come specially under the ban of our sanitary smoke consumers, and it may be well for the credit of the latter that it is so; for unless our open fires are changed for the close stoves of the Continent, there are no available means of changing the character or results of the process of combustion in that department.

In order more clearly to explain the distinctive characters of these two modes of combustion, I may state that there are two distinct stages in the decomposition of coal by heat, however that heat is applied. The first is a process of distillation.

When coal is exposed to a red heat, or even somewhat under a red heat, its constitution is immediately broken up, and this decomposition is independent of the combustion of the coal, as it takes place equally in close vessels where air is completely excluded. Thus in the closed retorts of the gas works we have the hydrogen, the volatile carbon, the nitrogen, and even the sulphur, expelled; for although this latter body, existing in the coal as sulphide of iron, is not in that form volatile, yet from its affinity for hydrogen it is almost entirely volatilised as sulphuretted hydrogen; and these volatile products being all expelled, we have the fixed carbon and the ashes or earthy matters, neither of which can be volatilised by heat, however long continued; the further decomposition belongs to the second stage, and is purely a process of combustion.

But do we in the first or distillatory stage, which takes place in our furnaces and open fires as well as in our gas retorts, simply eliminate the volatile constituents of our coal, as hydrogen, carbon nitrogen, and sulphur? Certainly not! these constituents, instead of leaving individually, form at the moment of their expulsion chemical unions giving rise to a most interesting series of compounds, many of which are well known, while some are only now coming under investigation, but all of which may be seen visible to the eye from our own parlour fires. For instance, our fire is getting low, and we call for coal to replenish it. The housemaid, after levelling down the nearly exhausted coke, dexterously places a couple of pieces of coal in as convenient a position as possible, and covers them up by pitching a lot of small out of the coal scuttle. After a slight crackling and splintering, shewing the non-conducting nature of the coal, a few streams of smoke come eddying up through the mass, of a white steamy appearance at first, being chiefly the moisture from the surface of the coal; but soon it becomes more dense and of a yellowish appearance. The distillation has now commenced; soon parts of the coal begin to swell and soften, and jets of the yellow smoke to issue from these softening masses. If the fire has been dull, this process goes on for a considerable time, and clouds of yellowish-white smoke pour lazily up the chimney, for its specific gravity being considerable, and being only slightly heated, it has no great ascending power. But what is the composition of this yellow vapour? It contains in perfect existence many substances of very different constitutions,—light carburetted-hydrogen gas (the explosive gas of the coal mine); olifient or heavy carburetted-hydrogen; or to give the others according to the present nomenclature, benzole, totuole, cumole, cymole, napthaline, para-napthaline, chrysine, pyrine, and hydrosulphuret of ammonia. All these substances in varying proportions, and each capable of being separated from the others, are while we look on slowly rising from our firegrate, and wending their way quite deliberately up the chimney, preparatory to pouring themselves down the throat of the first pedestrian they meet in the street. But to make the process a little more active, we now stir up the fire; the carbonaceous base of the combustible mass having accumulated heat, by being covered, now makes a sudden attack upon the overlying coals,—suddenly the distilling gases burst into flame at different points,—the distillation proceeds more rapidly,—larger volumes of the distillates are thrown off, and not being exceedingly inflammable, sometimes the flames are mastered and the yellow smoke prevails. The flames, however, keep encroaching and spreading over the mass, and now is the only time we have any trace of black deposit from our domestic fires; at this point of the combustion, so large is the mass of inflammable gases that perfect combustion never takes place; the intermediate products of combustion are all decomposed where the flame exists, though during the whole period of the distillatory process a considerable proportion of the distillates escape to the chimney unburnt; the hydrogen in the flame is all united with oxygen and forms water, but only part of the carbon gets converted into carbonic acid or oxide, and part is deposited as soot. One of the conditions of combustion is here in perfection, namely, abundance of oxygen, but for the other a sufficiently high temperature is wanting. As soon as the distillation draws to a close the combustion becomes perfect, the glowing of the carbonaceous mass and the play of the bluish lambent flame over the surface shew the conversion of the carbonic oxide into carbonic acid, and the remaining sulphur into sulphurous acid gas, and nothing now escapes the process.

These, then, are the characteristics and results of combustion in our domestic open fires. The smoke from our house chimneys consists to a large extent of the final products of combustion, carbonic acid gas, with the greater part of the smaller impregnation of sulphur in our house coals converted into sulphurous acid gas; with these will generally be mixed more or less of the tarry vapour products of distillation previously named, and occasionally a portion of carbon or soot, from the imperfect combustion by flame of these tarry vapour compounds; and besides all these, a varying proportion of carbonic oxide, making altogether a sufficiently noxious compound. Such as it is, however, the smoke consumer must take it; there are no means of improving it without a radical change in our domestic arrangements.

Leaving this department, we return to the investigation of the process of combustion, as conducted in the close furnaces of our steam boilers and in other manufacturing operations. In these processes, I take it for granted that there are used yearly in Manchester one million tons of coal, or one half the annual consumption. I may also say that they are the most impure kinds of coal, being the cheapest sorts, and we may therefore assume that of the two per cent. of sulphur given in the table No. 1 as the average for all the consumption, one per cent. is due to the house coal and *three* per cent. to the manufacturing coal. As to the other constituents the change is not material.

As before stated, in the close furnace we have the two stages in the decomposition of the coal, the same as in the retort or open fire; let us therefore first investigate the distillatory stage in the furnace. The stoker having stirred and withdrawn the clinkers from his furnace, throws on probably six to eight shovelfuls of coal. The distillatory process here being urged on not merely by the heat of the carbonaceous residue, but by the intense heat radiated from the brickwork of the furnace, commences instantaneously and proceeds with great rapidity. All the tarry vapour products, and also the sulphur as sulphurretted-hydrogen gas, and the nitrogen as ammonia, are poured out in dense volumes from the decomposing coal. Meantime the coke under the coal, from the previous stirring, is urged to a high state of combustion by the draught of air through the bars, and is able to sieze a large part of the passing oxygen and to combine with it as carbonic oxide. This, at an intense heat, mixes with the tarry vapour compounds and sulphuretted-hydrogen, and, assisted by the radiating heat from the brickwork, these vapours at once reach the heat of combustion; and were the other condition present, namely, a sufficient quantity of oxygen, the process of perfect combustion would at once take place. But, as we have seen, a large part of the oxygen is already appropriated; instead, therefore, of perfect combustion of all the products of the coal, a struggle now takes place as to which shall take or retain the limited amount of oxygen present. The first effects of that struggle are the decomposition of all the tarry vapour or hydro-carbon compounds, and also of the sulphuretted hydrogen; and now the hydrogen asserts its first claim to the oxygen, on the ground of the higher affinity,—all the oxygen unappropriated is at once laid hold of by the hydrogen, and if not then satisfied and the heat is sufficient, what hydrogen remains uncombined will then unite with oxygen at the expense of the carbonic oxide. Hence the dense dark cloud that now issues from the chimney, containing the immense volume of nearly pure carbon precipitated from the tarry vapours, and also partly from the carbonic oxide. Mixed with this mass, and in an innoxious condition, we may find the sulphur drawn from the coal as a distillate, through the affinity of the hydrogen gas, but again precipitated by the hydrogen from its greater preference for oxygen.

That this theory of the decomposition in the close furnaces is not only sustained by the known affinities of the bodies but by fact and observation, must be evident to any one who will not merely compare the appearance of the smoke from our domestic fires with that from our manufactories, but will compare the ordinary appearance of the smoke from the latter with that which it exhibits when the boiler fires are newly lighted, after being a sufficient time out of work to cool the internal brickwork. When the fires in this case are lighted up and coaled, instead of the black vapour we have a dense yellow-white mass issuing from the chimney, being the tarry vapours undecomposed; and this continues till the brickwork assumes its ordinary power of radiation to assist the decomposition.

Assuming then the correctness of this theory, we have, during the time that the distillatory process goes on vigorously, all the products of the coal flying off in an uncombined condition except the hydrogen, and as much carbonic oxide as escapes decomposition, by the hydrogen being all satisfied with oxygen. What then are the economical and sanitary bearings of the process during this period of the combustion? Economically we are obtaining the full equivalent of heat from the hydrogen gas, but in most cases all the volatile carbon is escaping without yielding any heat at all; and wherever the deficiency of oxygen is so great as to necessitate the decomposition of the carbonic oxide, to that extent a portion of the fixed carbon is also escaping, without yielding any equivalent of heat, while the other portion of fixed carbon volatilised by combustion during this period of the process is escaping as carbonic oxide gas, and thus yielding less than half the heat it would yield as carbonic acid gas.

Thus far the economical position. But what are the results in the sanitary department at *this period* of the process, which solely and exclusively engages the attention and anxiety of the sanitary smoke consumer, and to the improvement of which all his efforts are directed?

Decidedly and considerately I hazard the assertion, that this period of the process of combustion in our manufacturing operations is the very point where the least mischief is done to the sanitary condition of our atmosphere and the health of our populations. To sustain this assertion, let us attempt a somewhat hypothetical analysis of the gases issuing from the chimney during its continuance; and for this purpose I shall assume that the distillatory process takes half the time of the entire combustion, and that 100lbs. of coal are exposed to decomposition. Assuming, then, that oxygen passes through the bars sufficient to oxidise one-half of the fixed carbon of the coal as carbonic oxide, and an excess of oxygen passes equal to one-half of the hydrogen, we shall then have 57lbs. of oxygen, or 255 lbs. of air, passing through the fire; the exit at the chimney will therefore be, on the assumption of the correctness of my hypothesis, as follows:—

198·	lbs.	Nitrogen Gas.
39·6	"	Water, as Steam.
29·	"	Carbonic Oxide Gas.
31·5	"	Carbon, as Soot.
2·	"	Sulphur, as Soot or Solid.
1·	"	Carbonate of Ammonia, or Sulphide of Ammonium.

Of these constituents of the smoke only one is of a character positively deleterious to health. Nitrogen gas is purely negative, and is not altered by passing through the fire. The water needs no defence; the solid carbon, against which all the cry is raised, is guiltless of any deleterious effect on human health, is one of the most antiputrescent bodies, and while floating in the atmosphere does all that it can to arrest and destroy noxious and miasmatic vapours. Sulphur, again, in its solid form, is perfectly innoxious. The only objectionable body is the carbonic oxide gas; this is certainly poisonous, being equal in that respect at least to carbonic acid gas. It has, however, this advantage, that while carbonic acid gas has a specific gravity of 1·52, air being 1·0, and is thus more than 50 per cent. heavier than air, the specific gravity of carbonic oxide is only ·96, or somewhat less than air; it is thus not only aided in its escape by the law of diffusion, but its lightness always prevents it from any tendency to descend to the human dwellings around.

I might now contrast the preceding hypothetical—yet I venture to say very probable—analysis of the black smoke of the distillatory stage in the boiler furnace, with the succeeding stage of the process of combustion, when the residuary coke only is undergoing that process, and the chimney throws out only a thin haze of smoke hardly visible; and might show that here, while our nitrogen remains the same, we have added to our carbonic oxide gas more than double its weight of carbonic acid gas. But instead of tabulating the results of this latter stage of the process, I shall meet the case of the smoke consumer exactly, by supposing that he and the economist together have fairly mastered their difficulty;—that the economist, by getting perfect combustion of his fuel in the first or distillatory stage of the process, has not only got the economical value of his coal, but has also been able perfectly to satisfy the sanitary smoke consumer, being in a condition to point to his chimney-top as now guiltless of sending out anything *visible* which can prejudice the health of the community. But suppose that we distrust appearances, and again resort to our analysis,—not in this instance partaking much of hypothesis, but coming near to certainty. For the distillatory stage, we shall in this case have to send through the bars 178 lbs. of oxygen, or 746 lbs. of air; the chimney-top will at the same time emit—

568·	lbs.	Nitrogen Gas.
163·	"	Carbonic Acid Gas.
39·6	"	Water.
5·5	"	Sulphurous Acid Gas.
1·	"	Sulphite of Ammonia.

Now, I put it to the sanitary smoke consumer to make his choice:—Will he consent to have from every 100 lbs. of coal, during the distillatory stage of combustion, 29 lbs. of poisonous carbonic oxide gas—prevented by its levity and the law of diffusion from invading the lower regions of the atmosphere—and at the same time bear with the black smoke which confines its ravages to the destruction of the purity of his linen; or will he choose instead, 163 lbs. of heavy carbonic acid gas, descending around him by its specific weight despite the law of diffusion, and so poisonous in its character that it is an ascertained fact that 7 per cent. of it diffused in the atmosphere is immediately destructive of animal life?

These facts contain the elements of his choice, or the points of difference between the sanitary condition of our atmosphere as the receptacle of the products of imperfect combustion in our manufacturing operations, and what it will be when perfect combustion is attained. And while I state my conviction that the large inducement which the economical view of the matter presents, will furnish a motive for striving to perfect the process, which will now go on without the aid of the sanitary smoke consumer,—and that we shall, slowly it may be, but certainly, arrive at the results pointed at,—I nevertheless look upon the change as involving a most serious impending evil. Deleterious already, and weakening to the vital powers, as our atmosphere is, that evil will doubtless be greatly increased by the very means by which it is now sought to lessen it. So convinced am I of this, that I look as the only hope to the time when the evil will call imperatively for a remedy, and of an essentially different character to the one now so pressingly urged.

Let us look at the tabulated results of perfect combustion of our present quantity of coal for manufacturing purposes,—taking for granted that while we are going on to reach that point, no increase of coal will be needed, the increase of work to be done being obtained by improved modes of consumption. Our one million of tons of coal will yield by perfect combustion—

3,006,666	tons of	Carbonic Acid Gas.
500,000	"	Water.
60,000	"	Sulphuric Acid Gas.
10,000	"	Sulphate of Ammonia.

Now to shew that the evil is not an imaginary one, let us reduce it to the amount of deterioration during a working day, of which we may take 300 in the year; we shall then have thrown, in the twelve hours of every working day, upon an atmosphere already deteriorated and foul—

10,260 tons of Carbonic Acid Gas, and
200 " Sulphurous Acid Gas,
the equivalent of about 290 tons of Vitriol.

Assuming, then, the atmosphere of Manchester as inclosed within a ring of 2½ miles diameter, and to extend to 45 feet in height, we have thus a mass of air measuring 217,800,000 cubic yards; the bulk of carbonic acid gas produced being 10,260 tons per day, will be 8,000,000 cubic yards, which added to the impregnation from our dwelling-house fires would give us at least the quantity of 7 per cent. produced during a working day,—which, if we could suppose it to accumulate in that space, would render the whole area as instantly destructive to life as the *Grotto del Cane*, or the workings of a coal mine after an explosion of carburetted hydrogen gas.

I do not, however, present this as an occurrence within the range of possibility, although it may be quite rational to assume the likelihood of its happening in some particular localities in very peculiar atmospheric circumstances; but without supposing the possibility of such a fearful catastrophe, the idea is sufficiently horrible that we shall have at all times floating around us such a mass of atmospheric poison, which we must to a certain extent inhale, and from the deleterious influence of which we cannot entirely escape. But in addition to the carbonic acid we shall have for every working day the diffusion of about 200 tons of sulphurous acid gas, which having a specific gravity of 2.2, and thus being more than double the weight of air, will under almost any circumstances descend to the lower strata of the atmosphere, and surround us, destroying vegetation, and though in itself one of the best correctives of miasma, yet certainly a most insalubrious atmosphere to breathe constantly.

The prospect thus held out as to the well-being of our town population is certainly not a very cheering one, and it may seem that while pointing out the mistake into which the sanitary smoke consumer has fallen, I am doing my utmost to effect the same amount of mischief, by presenting so strong an inducement to the possible economising of fuel; but as the mischief is apparently inevitable, it seems the best that can be done to probe the disease to the bottom.

A remedy I believe to be possible; and though the one which I shall take the liberty to indicate may now be looked upon as chimerical, it is one that I have not the slightest doubt we shall ultimately be driven to adopt.

We cannot remove from the atmosphere the immense volume of gases produced by our coal combustion: this is impossible; but it is possible to confine those gases so as to separate them entirely from that portion of the atmosphere in which we live, and to convey them into the vast atmospheric ocean over our heads at a point which would effectually preclude their returning upon us.

I should propose, then, a system of *atmospheric* or *gaseous sewerage*, and the complete removal of all these gases to a safe distance from our towns. The original suggestion of a mode for effecting this object is not mine, and I therefore disclaim all the credit that may attach to its author; but I am not aware of its having ever been given to the public in a practicable shape, and there are some views of the matter which may be safely presented as new. I would combine this gaseous sewerage in such a form with our town drainage, as would bring all the liquid sewage into contact with the gasses from our furnaces and our house fires, the liquid sewage being kept, as now generally proposed, separate from all surface drainage. The semi-liquid and fetid mass being brought into contact with the sulphurous acid gas (the result of our perfect combustion), would have its putrefactive process arrested and the foul emanations neutralised,—all its ammonia converted into sulphite and thus permanently fixed, and all the sulphuretted hydrogen and other unwholesome gases decomposed. When concentrated in this innoxious form from various districts to a convenient place, it might with perfect safety be manufactured into manure more valuable than the richest guano, as I shall afterwards attempt to shew. All the gases from our coal combustion would have to be conveyed along the same tunnels to centralizing conduits converging to a point, where an immense chimney, at least 600 feet high, should be erected, to discharge these gases into the atmosphere,—the ascensive power being obtained either from the retained heat of these gases, which would probably be found quite sufficient, or if not, artificial heat could then be supplied to effect that object.

As the idea of one chimney being sufficient for all the furnaces and domestic fires of Manchester will, on its first announcement, be looked upon as preposterous, I shall first give the size and cost of the chimney proposed, and shall then demonstrate its more than sufficiency for the purpose. The chimney should be 600 feet high, 100 feet internal diameter at the top, 140 feet external diameter at the bottom, and its walls 10 feet thick at the bottom and 2 feet thick at the top. To build this would require 18,200,000 bricks, or with the addition of 1,800,000 for foundation, say 20,000,000, which would cost at present in Manchester under £15,000.; another £25,000. would probably build it, making the total cost about £10,000. The weight of the chimney would be 72,000 tons, and it would exert a pressure on the area of its foundation (say of 150 feet square) of less than 50 lbs. per square inch, or less than the pressure which a man of 12 stones weight would exert who should stand for a moment on his heel or tiptoe. Thus there would be no fear of insecurity from that cause. It would supersede say 500 chimneys in Manchester, costing at an average £500. each, or £250,000. But it may be asked, having built our large chimney, will it be sufficiently capacious to pass all the gases resulting from the combustion of our two million tons of coal? These gases will amount in volume to about the same as the air required for perfect combustion of the coal. Two million tons of coal require for perfect combustion 16,710,000,000 cubic yards of air; this divided by 365 = 45,789,000 cubic yards per day.

The area of our chimney at its smallest diameter is 7,500 feet; this gives a column of air of 7,500 × 600 = 4,500,000 cubic feet; and the weight of this at 60 Fahr. is 334,285 lbs. Suppose, then, that all our gases when entering the chimney are at a temperature of 100 Fahr., or that they are expanded by 40 degrees above atmospheric temperature, the column will then weigh 307,543 lbs., and thus we shall have an ascensive power of 26,742 lbs. Now 100 Fahr. is only a little above blood heat; and as all the gases from our boiler furnaces would enter the conducting flues at a heat of 250 degrees or upwards, it is not assuming too much to take it for granted that without assistance we should have a regular heat in our chimney of 100 Fahr. But $\frac{26742}{7500}$ on an area of 7,500 feet gives a pressure of more than 3½ lbs. per square foot, and this again, according to the ascertained law of the pressure of air in motion, gives a velocity of 42 feet per second, or, deducting the 2 feet per second for friction on the sides of our chimney, will give us a free velocity of 40 feet per second. This, only allowing twelve hours per day, and not taking into account what passes during the twelve hours of the night, shows—40 feet × 7,500 × 60 sec. × 60 min. × 12 hours = 12,960,000,000 cubic feet, or 480 millions of cubic yards per day of twelve hours. Thus, while our two million tons of coal divided by 365 days, require only space and draught for 45,789,000 cubic yards per day, we can actually, with our proposed chimney pass 480 millions per day, or more than *ten times* what is actually requisite.

This leads me to state one of the vast advantages of the plan now proposed. In alluding to the system lately propounded and strongly advocated in "The Times" for sewering and taking away all the excreta of London, I characterised it as a clumsy scheme. It makes no provision for either neutralising or getting rid of the pestiferous gases or effluvia by which fever, consumption, and cholera are nourished; nay, it provides for the whole under-strata of London being actually saturated with these gases, as it proposes to accumulate and retain the fetid abominations, while they slowly wend their way through nearly level culverts to the place of their exit, giving just sufficient time for the full development of the putrefactive process, by which the deadly gases will be evolved in such abundance that no trapping will be sufficient to confine, and almost no building be able to prevent them from leaking, when pent up as they will be by this costly yet crude arrangement.

Now in the plan here proposed, provision is made, as I shall more fully explain, for the neutralisation of the liquid filth, the stopping of the putrefactive process, and the decomposition of all that is deadly arising from the sewerage; but at the same time a power is provided that will be able to lay hold of all the gaseous emanations, and drag them off so pertinaciously and effectually that it will be utterly impossible for one breath of them ever to be felt where it is in operation. Our chimney having an excess of nine-tenths of its draught, and being connected with all the town sewers, will effectually carry off every particle of foul emanations from thence; and every leak or opening to the upward air from these sewers would not then emit foul gases, but draw in fresh air with a pressure or suction of three and a half pounds per foot, or a velocity of 40 feet per second.

This I consider is one of the most valuable features of the scheme, and the principle involved in it as essential to the sanitary condition of our towns. It is idle to talk of trapping, and thus confining gases evolved under-ground; exit they must and will have, and when you imagine you have secured them in one place you will find them pouring out from another. I shall, however, probably make this matter plainer by an illustration. I lately took an old fashioned detached house. After entering into possession, I found frequently very disagreeable smells, especially after rain, a change of wind, or a fall of the barometer. They evidently belonged to the sewerage.

No time was lost in getting all the exits newly trapped with the most approved patent grids; all slopstone pipes, &c., were cut and waterluted. But it was of no use; it came through the very walls and floors, and one bed-room on the first floor which shewed no apparent connection with the sewer was quiet uninhabitable. What was to be done? I had exhausted all the remedies which the philosophy of the London scheme acknowledges, and yet the evil was uncured. I adopted a plan which it does *not* acknowledge;—a branch from the main sewer was brought right under the kitchen grate, from that a pipe of cast iron, four inches diameter, was carried up through the brickwork behind the kitchen fire, and the open top projected into the chimney a yard and a half above the fire. When this fire was again lighted, in a few hours all the house was perfectly sweet, and the distant bedroom, uninhabitable before, has been slept in ever since. Now, if no provision is made for separating and conveying completely away to a safe distance the effluvia from the accumulated excreta of London, the scheme will turn out to be a futile and dangerous one. By separating the surface drainage, and thus concentrating the sewage as much as possible in order to lessen the quantity, the exact requirements for energetic putrefaction will be provided. Dilution below a certain point is adverse to putrefaction; that dilution will at present be the general state of the sewage, but with the separate sewering plan it will be the exception, and the putrefactive process will have full play.

But to bring the matter to a close, I shall introduce another feature of my plan, and then leave it to the consideration of the thoughtful. One of the subjects now most frequently discussed in connection with the sewage of towns, is its value and applicability as a manure. London has been peculiarly the scene of these discussions in various shapes, and it would seem from the plan now proposed of carrying off the sewage and pouring it into the tide, that whatever its ascertained value, its inapplicability as a manure is a settled point. To this* mode of settling the question I feel the utmost repugnance. Nature, provident of means in effecting all its objects, has established certain laws of connection between the animal and vegetable kingdoms, and while the observation of some of these laws in operation may only serve to point a moral or be suggestive of principles for our guidance, the observation of others will afford us rules by which our conduct may be regulated, so that by acting in accordance with these laws we may enjoy the benefits which always flow from obedience to them.

In the animal kingdom the air which is breathed has its oxygen retained and changed in the animal economy into carbonic acid, and those other oxygenated compounds which the animal system is constantly throwing off while the vital process goes on. The vegetable kingdom, as if depending on the higher class of organisation, not only breathes and is sustained and built up by the carbonic acid expelled by the animal organisms, but lays hold with avidity, and luxuriates upon, those various forms of excreta which the animal life has thrown off. With regard to the merely atmospheric operation of this law, our duty is limited ; it is needful for us to take care that the animal system has its full supply of oxygen, and has room to throw off the carbonic acid, and there our activity terminates. Nature will provide for the diffusion of that carbonic acid, and will not fail to afford to every vegetable existence its full supply to sustain and build it up. But those other essential constituents of the vegetable life which they obtain at a vast expense of time and energy—the phosphates, the silicates of soda and potash, and the combined nitrogen, all of which have to be sought for slowly by the far-spreading roots of the vegetable structures—are dependent on the operation of heat and cold, and moist and dry, disintegrating the rocks, the debris from which slowly and reluctantly yield them up to the living vegetable forces ; but when these substances thus painfully acquired are handed over by the vegetable kingdom in the various forms in which it affords food to the animal economy, and they again, after sustaining and combining with the animal structures, are thrown off in the various forms of excreta, they become then in the fittest condition for sustaining, and maturing, and increasing the production of those very classes of vegetable existences from which as food they were extracted. And I think there is not the slightest reason to doubt that, theoretically, if the whole excreta of London's two-and-a-half millions of people were absolutely economised, and all applied with absolute knowledge to the soil in proper proportions, it would cause an *additional* growth to what the soil without its aid would yield, of exactly as much as the food represented by that excreta ; so that with a wise economy of our resources up to a point when the utmost that all our land could be made to yield is produced—and we are yet very far from such a point—instead of increased population pressing upon the means of existence, the means of existence would keep regularly and systematically ahead of the population.

What, then, is our present position on this important subject, and which is so closely allied with the sanitary question? Theoretically we seem to have ascertained that the food which our populations consume contains certain elements derived from the soil which produced that food, which were essential to its production, and which are by no means destroyed by entering as food into the animal economy and becoming constituents of the bodily structures, but are faithfully rendered up again as excreta, and become the elements of another equal supply of food. Thus far the *theory* which connects itself with the supply of the most pressing of our necessities,—the production of our daily food. Is our *practice* in accordance with it? As in many of our operations so in this, our practice has existed long before any theory on the subject, either true or false, has been sought for. From time immemorial the elements derived from the soil have been partially returned to it by a limited use of the excreta chiefly of the lower animals, but by far the larger portion of these elements, from ignorance of their value, and from practical difficulties as to their application, have been most improvidently wasted. Nature, by means even of the disagreeable forms with which she has invested them, has been calling on us to return them to the soil, that she might transform them into the beautiful and the useful; but we have preferred to send them to pollute our rivers, and almost to contaminate the ocean itself, and have sent nature back to the exhausted soil to renew the search for those elements of the vegetable structures of which we have so unwisely robbed her; and when she has failed in finding the needful amount of these elements, and been consequently unable to mature the produce we required of her, we blamed the seasons, and thus tacitly and often avowedly threw back on the bountiful Author of seed-time and harvest, as the result of His decrees, what was simply the result of our own ignorance. We are now, however, awaking to a full sense of the importance of rendering back to the soil what is withdrawn from it as food; nay, we are traversing the ocean in order to find in a portable form the excreta of the millions of birds which tenant the isles and coasts of the southern hemisphere; but as yet we are practically ignoring the fact that the sewage of our towns contains in quantity and kind all that is needful to replenish our soil, and to make it increasingly productive.

As the fact of the excreta containing the equivalent of the food consumed in elements essential to vegetation will not be questioned by any who have studied the chemistry of the animal economy, I shall take it for granted that the sole barrier to its universal application is the practical difficulties to be overcome. The use of the sewage of towns in a liquid form has been amply discussed, and is at present looked on as almost hopeless. Precipitation of the solid from the liquid has been attempted, and several plans for effecting this are now in operation, with not much promise of success. All of these have necessarily failed from the fact that they have not even attempted to arrest the ammonia, the most valuable constituent of the sewage. There is, indeed, a plan for precipitation (that of Dr. Angus Smith and Mr. M'Dougall), which does profess to arrest and fix the ammonia, and apparently on scientific principles; but it has not yet been brought into operation. The third and only other mode that remains is to convert the sewage into a dry substance by evaporation, having previously fixed all its volatile constituents. By this mode of course all its value would be economised, and its application be rendered easy. It thus becomes only a question of the expense of the process and value of the result.

Returning, then, to my proposal, I shall be able to shew that if in any shape this mode of economising our town sewage is to be made a practical operation, the plan I propose will most decidedly facilitate that result. The underground channels for conveying the waste gases of our coal combustion to the one great chimney would also be the channels for the sewage, which, separated from all surface drainage, would thus be in as concentrated a form as possible; the sulphurous acid gas of our furnaces and fires would, by coming into contact in these channels, neutralise all its putrefactive properties, and covert all its ammonia into sulphite; thus entirely preventing its escape at any future stage of the process, so that when converted into a dry manure every atom of the combined nitrogen will be available as a fertiliser. But besides all this beneficial action of the waste gases on the sewage, they become themselves the direct source of a most valuable deposit, which has never yet been looked on as one of the elements of benefit to be derived from the excreta of our towns. Ammonia, in one form or another, is one of the invariable results of our coal combustion. It is well known that it is one of the regular products of the large process of coal distillation carried on in our gas works. Experimental results of a very accurate character were many years ago given by Bunsen and Playfair, as to the amount of ammonia yielded by coal subjected to the distillatory process. These results of experiment correspond almost exactly with those yielded on the much larger scale at our various gas works. Having had all the ammoniacal liquors of the Manchester and Salford Gas Works passing under my observation for several years, I am able to give this with considerable accuracy. The average quantity yielded is about the equivalent of 20 to 24 lbs. of sulphate of ammonia for every ton of coal; but as these results, both experimental and on the larger scale, have respect only to the distillatory process, an important question still requires solution, namely, whether the production of ammonia remains constant when the coal is subjected to partial or perfect combustion.

There appeared in the Journal of the Society of Arts, London, about twelve months ago, a statement said to have been made in a lecture delivered before that society by Professor F. C. Calvert, and under the presidency of Dr. Lyon Playfair, in which it was announced that in one of our large processes, the conversion of coal into coke in our coke ovens, ammonia was produced and wasted by being thrown into the atmosphere in the proportion of six tons of sulphate of ammonia for every 100 tons of coal operated upon. If this statement were the result of experiment, and could be depended upon, it would prove that not only is an equal quantity of ammonia produced by partial combustion of the coal as by the distillatory process of the gas works, but that actually six times the amount is produced in the partial combustion of the coke oven that there is by distillation in the gas retort. I am, however, afraid that the quantity mentioned is considerably above what is actually produced, and is only a calculation of what the combined nitrogen of the coal ought to generate.

Dr. Angus Smith kindly undertook a series of experiments for me in order to elucidate the real facts of the case in this matter; and although they do not fully exhaust the subject, they prove that in no case does it seem possible to obtain an approximation to the quantity said by Professor Calvert to be given. Yet that a quantity equivalent to 35 lbs. of sulphate of ammonia per ton of coal. or upwards of 1½ tons per 100 tons of coal, is in certain cases obtainable,—and as it also resulted from these experiments that a considerable amount of nitrogen is held in an apparently mechanical combination by the coke after distillation of the coal,—and as in perfect combustion this would probably all be converted into ammonia;—we have reason to conclude that perfect combustion will yield a larger product of ammonia than either the distillatory process of the gas manufacture or the partial combustion of the coke process.

It will, then, form a perfectly safe basis for calculation if we take one-sixth of the probable theoretical quantity given by Professor Calvert, or 22·4 lbs. of sulphate of ammonia, for every ton of coal consumed, and this gives a starting-point for the following calculations of what is possible and practicable in an economical point of view from the adoption of my plan, with the waste gases of our coal consumption:—

The production of sulphate of ammonia from one ton of coal being 22·4 lbs., our two million of tons of coal will yield, on the adoption of my plan, 20,000 tons of sulphate of ammonia, all of which would be deposited in the tunnels, and be added to the sewage. The value of sulphate of ammonia as a fertilizer is not now a doubtful question. Its money value, at its average market price of £15. (its present price for manure being £20.) per ton, would be £300,000., rather a heavy sum to dissipate in smoke.

To ascertain the value of the sewage of Manchester is a difficult problem. We have no certain data as to its value in phosphates, alkaline sulphates, and silicites, or other fertilizing constituents; but allowing these to be merely additions to the value of the resulting manure, we may get an approximation to the quantity of ammonia contained in it as bearing a known proportion of the population; and from the closest investigation of data furnished by various authorities, this cannot be less than the equivalent of 70 lbs. of sulphate of ammonia per annum for each of the population. The quantity is probably somewhat beyond this, but it does not appear that it can be less. This for a population of 400,000 is 12,500 tons of sulphate of ammonia per annum, contained in the sewage of Manchester and Salford. The money value of this again is £187,500. for a commodity now only devoted to the pollution of the river Irwell, which is thereby converted into a huge foul-water trough, in which the only life is the constant bubbling of the putrefactive gases emanating from its black slimy deposit.

But this is not the only mode in which the money value of the sewage can be estimated. If when thus combined with the deposit from our coal combustion the whole can be manufactured into a dry manure, its use will be practically unlimited; and looking at it as so manufactured, and taking the sulphate of ammonia as the basis of its value, we shall find that if we produce a compound containing carbon, sulphates of the alkalis, phosphates, and silicates, all which exist in the sewage, and holding 4 cwt. of sulphate of ammonia per ton of the compound, we should have a manure more valuable as a fertiliser than either the artificial or the average of the natural guanos.

The sewage of Manchester and Salford, aided by the proposed plan of treating the gaseous results of all our coal combustion, taking 4 cwt. per ton of sulphate of ammonia as the basis of the calculation, would yield of this artificial guano, 162,500 tons, of a quality which at £5. per ton would be cheaper than any of those now in use. The gross value of the whole at this price per ton would be the enormous sum of £812,500.

This seems a fair, in fact a very low estimate of the value of the produce from the proposed manufacture. The next question is the expense of the process. The manufacture of the manure would be a simple process of evaporation, and its expense could at once be estimated if we were possessed of data as to the proportion of liquid to solid in the sewage, or what amount of evaporation would be required to produce one ton of our dry compound. As in such an immense manufacture we may calculate on the best arrangements being adopted for economising heat, we may safely look for an evaporation of ten tons of water from every ton of coal used; and as we could in most localities afford to use from three to four tons of coal in producing one ton of the manure, it may be assumed that if the liquid in our sewage does not bear a higher proportion to the solid than 40 to 1, our manufacture could be unhesitatingly proceeded with: if above this proportion, it might be restricted to particular localities where coal was abundant. The probability is that it could generally be manufactured at much less than half its assumed value, leaving a sum, after deducting expenses of sale, of from £300,000. to £400,000. annually as a financial inducement to undertake the scheme. Even on this narrow ground, then, it presents inducements to our capitalists of a more substantial kind than many of those undertakings in which millions of money are expended.

But promising as are the financial probabilities of the scheme, they are insignificant when compared with the benefits in a sanitary point of view which the successful introduction of the plan in its integrity would insure, namely,—the removal from the interior of all our dwellings, from the mansion to the cottage, and even to the cellar, of the slightest trace of those pestiferous emanations which feed our fevers, consumption, and cholera, and which now more than any other merely physical cause servo to lower the vital energies of our town populations, making them an easy prey to every epidemic. Instead of the atmosphere of our towns being, as now, a dim, and dull, and murky compound of black and yellow and grey smoke, blended into a haze, and containing besides its proper elements a mixture of carbon, carbonic oxide, carbonic acid, and sulphurous acid gases, with the condensible hydro-carbon compounds of our domestic fires, we should then continually revel in an atmosphere transparent, pure, and salubrious as that which encircles the mountain's side, or reclines on the ocean's bosom; and instead of vegetation with its cheering green being banished from the interior of our towns, and even in their suburbs holding only a stunted, miserable, and withering struggle for life, every nook and corner where light could descend might then have its shrub or its tree; our most bustling streets might be enlivened by the evergreen leaves of the climbing ivy, or with other parasitical plants, and might be made fragrant to the smell, while the eye was delighted with their beautiful and variegated flowers. The intense mental and physical activity of human life in our vast populations, would not then have superadded to the exhausting effects of this incessant toil on the human constitution, the depressing tendency of an impure and fetid atmosphere; town life would become not only endurable but exhilarating; health would become more vigorous, disease more moderate; epidemics would more seldom appear, and the dreaded pestilence finding no victims prepared for its ravages, would bid us a final adieu.

These are not extravagant anticipations, but legitimate deductions from the data exhibited. The subject is one of great and pressing importance; and it claims the sympathy of the thoughtful, of the philanthropical, of every one in fact who values the life, the health and comfort of himself and his fellow-men. As to its ultimate accomplishment, this I am convinced is only a matter of time, and my hope is that these remarks may lead to its being contemplated not as a chimera, but as a most desirable and practicable reality.

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